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OBJECTIVE ANALYSIS OF THE SEA SURFACE TEMPERATURE

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ABSTRACT

A program has been developed which analyzes sea surface temperatures on an operational and research basis. Data were composited for five-day periods from the thirteenth to the seventeenth for the months of June, August, September, and October during the 1972 hurricane season Sea surface temperature and anomaly charts were computed. These charts are discussed in relation to tropical cyclone activity.

INTRODUCTION

During the past twenty-five years numerous people have investigated the sea surface temperature (SST) field and its relationship to tropical cyclone activity. The classic paper by Palmen (1948) showed that the oceanic regions of frequent tropical cyclone formation are climatologically associated with sea surface temperatures above 26-27C. Other studies have been made indicating a close association of tropical cyclone intensity with SST on a shorter time scale (e.g. Fisher, 1958; Miller, 1958; Perlroth, 1962; Smith, 1972). Ooyama (1969) conducted several numerical experiments with an axisymmetric tropical cyclone model in which he varied the value of the SST over selected areas. The results agreed reasonably well with the studies mentioned above.

For years hurricane forecasters have realized the importance of the field of SST and its possible effects on tropical cyclone activity. While Taylor (1966) in his study of several hurricanes in the Gulf of Mexico demonstrated the feasibility of producing SST charts in real time over a limited domain by manual methods, routine production of such charts over a broad area has had to await the development of computerized procedures. Although a description of the SST field is valuable in assessing the probability of tropical cyclone formation or intensification, the time required to manually average, plot and analyze SST values for three-, five-, ten-, or thirty-day periods is time the forecaster can ill-afford when a storm is in progress.

Simpson (1971) created a series of decision ladders to determine the development potential of a tropical cyclone. Since that time computer programs have been formulated to compute various numerical quantities (e.g. vertical shear, line integrals of mass flow, sea surface temperature) in and around a tropical cyclone so that a quantitative estimate of the development potential can be made. Also, with numerical models it will be necessary to objectively analyze the initial data. Two important initial quantities necessary in the computation of the vertical flux of latent and sensible heat from the ocean are the analyzed air and sea surface temperatures. For these reasons a computer program was written to objectively analyze the SST using all available SST observations in a particular time period.

THE OBJECTIVE ANALYSIS

The objective analysis method is of the circular scan type and is essentially the one devised by Cressman (1959). It involves making corrections to initial values at grid points using actual data within some given radial distance of each point. These corrections are weighted according to the distance of the actual data from the grid point. The grid points are corrected four or five times using data within successively smaller circular areas.

The initial or first guess field consists of sea surface mean temperatures. Means were computed by using all of the observations within one degree quadrangles for each month during the years 1941 through 1971. The Scripps Institution of Oceanography provided means based on observations by the U. S. Navy, Coast Guard, Coast and Geodetic Survey, National Marine Fisheries Service, Duke University, Texas A&M University, University of Miami, Woods Hole Oceanographic Institute, and a few British research and naval ships. The use of a monthly mean in the program serves three important purposes: 1) It is an ideal first guess field, 2) it can be used to check isolated station reports by allowing only acceptable deviations of the SST values, 3) it can be used to compute anomalies.

The bulk of the SST data is obtained from 0000 GMT daily and 1200 GMT marine observations which are decoded and accumulated daily by computer at the National Meteorological Center (NMC). SST observations from oil rigs, buoys, and other sources can be added at execution of the program.

Erroneous observations are handled by using a "buddy" data check system obtained from the NMC and modified to apply to sea surface temperatures. As mentioned above, isolated observations are checked against the monthly mean. Areas devoid of observations will have the monthly mean as the final analysis.

The analysis is carried out over a domain from 5.0W to 123.5W and from the equator to 45.0N. The grid is 35 by 80 and the distance between grid points is 167 kilometers.

This study is concerned with the SST values and anomalies computed for five days of observations centered on the fifteenth of the months June, August, September, and October 1972. Because of the conservative nature of the SST on a synoptic scale the mid-month SST analyses and anomalies should be good indicators of the synoptic scale monthly changes.

RESULTS

Figures 1, 3, 5, and 7 show objectively analyzed sea surface temperatures in fahrenheit degrees (F) using 0000 GMT and 1200 GMT marine observations for 13-17 June, August, September, and October 1972, respectively. The 80F value is considered the threshold for tropical cyclone formation, after Palmén (1948). Once a tropical cyclone has formed within the 80F region the hurricane forecaster is concerned whether or not it will move into or close to an area of very warm SST where it might intensify due to the more ready availability of latent and sensible heat.

In figure 1 the contrast between the Eastern Pacific region and the tropical Atlantic is evident. Large areas with temperatures greater than 84F exist in the Eastern Pacific while in the Atlantic only one small area can be found (4.5N - 41.5W).

In figure 3 the warming that has occurred over both regions is evident from the increase in the areas enclosed by the 80F isotherm. The Eastern Pacific has not only a very extensive area in which temperatures are greater than 84F but also a very large area of SST warmer than 84F. The Gulf of Mexico and the Caribbean have large areas where SSTs exceed 84F. The small area of SST warmer than 84F found in June in the Atlantic has disappeared.

Figure 5 shows a cooling in the Eastern Pacific region as the areas of SST above 84F and 86F begin to decrease in size. The Atlantic, Gulf of Mexico and Caribbean have continued to warm and there are several areas warmer than 84F with a few small areas warmer than 86F.

Figure 7 shows that the Eastern Pacific has continued to cool with the areas of SST warmer than 84F and 86F becoming still smaller. The Gulf of Mexico and Northern Tropical Atlantic have cooled considerably while the Caribbean and Southern Tropical Atlantic have several large areas where SSTs exceed 84F.

Figures 2, 4, 6, and 8 show the sea surface temperature anomalies in fahrenheit degrees (F) for 13-17 June, August, September, and October 1972, respectively. The anomalies are computed by subtracting the respective monthly means from figures 1, 3, 5,and 7. In interpreting the anomaly fields it is necessary to know that data-void regions will have monthly means as the final SST analyses and, consequently, zero anomalies. However, zero anomalies may also result from SST analysis over regions where data exist. Therefore, care must be taken in the interpretation of zero-anomaly regions.

Examination of figures 2, 4 and 6 reveals several important features. In the Atlantic region from the equator to about 10N there are large areas where SSTs were consistently 1-2F above normal. More importantly, from approximately 10N to 35N there are large areas with SST 1-3F below normal. Finally, north of 35N there are areas with SST 1-3F above normal. Most noticeable in the Eastern Pacific region of these charts are areas with SST 1-4F above normal. Temperatures were above normal over almost the entire Eastern Pacific during August (Fig. 4). Temperatures in the Caribbean tended to remain below normal while in the Gulf of Mexico they were generally normal.

Figure 8 shows that during October over the entire domain large areas with SST 1-3F above normal were found except for the northeastern region of the tropical Atlantic where SST values were 1-3F below normal.

REVIEW OF THE 1972 HURRICANE SEASONS OF THE ATLANTIC AND EASTERN PACIFIC

Figure 9 shows the tracks of the four named Atlantic storms of 1972. Three storms reached hurricane intensity but would be classified as minimal. Normally the Atlantic experiences nine storms with five to six reaching hurricane intensity.[1] Frank (1973) documented the total number of disturbances and depressions occurring in the Atlantic in 1972 and compared these with a five-year sample (1968-1972). The total number of depressions was twenty-four, which is the average for the five-year sample. The total number of disturbances was 113, which is ten above the average of 103. One major conclusion can be made: the below normal Atlantic hurricane season was not due to a lack of disturbances.

Figure 10 shows the tracks of the twelve named Eastern Pacific storms of 1972. This is three below the average of fifteen.[1] However, eight of these storms developed into hurricanes, compared to the normal of seven. Most striking is the fact that six of the eight hurricanes that formed did so in the month of August.

SEA SURFACE TEMPERATURE ANOMALIES AND TROPICAL CYCLONE ACTIVITY

Several points can be made concerning tropical cyclone activity and the SST anomalies in the Atlantic. Hurricane Agnes, tropical storm Carrie, and hurricane Dawn formed where the sea surface temperatures were near normal. Hurricane Betty formed between 35W and 40W where the SST was 1-3F above normal, although the area of formation was bordering on 80F. The fact that no tropical cyclone formation took place from 10N to 35N and east of 70W is very significant. This is the region where the large areas of SST 1-3F below normal existed during June, August, and September (Figures 2, 4 and 6).

The Eastern Pacific in June, August, September and October exhibited large areas of SST anomalies 1-3F above normal. Although the total number of storms (12) was below the normal by three, there was an above normal number of hurricanes. Perhaps the most important point is the fact that during August, when the SST values were 1-3F above normal, six hurricanes formed in the Eastern Pacific.

It is necessary to emphasize again that the SST is only one of several factors related to tropical cyclone formation and intensification. Without further information the possibility cannot be ruled out that large values of vertical wind shear also played a major role in suppressing tropical cyclone formation in the Atlantic.

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[1] Averages are based on seven years of data (1966-1972).

CONCLUSIONS

A relationship exists between tropical cyclone activity (i.e. formation and intensification) and sea surface temperature. The real-time, objective analysis of sea surface temperature and computation of anomalies identify those areas of warm SST which can serve as ready sources of energy for development or intensification of tropical cyclones. It is therefore considered desirable that: (1) routine five-, ten-, and thirty-day SST charts and anomalies be computed during the hurricane season; (2) during storm situations and where the data permit one- and two-day SST charts and anomalies be computed; and (3) experimental charts of the vertical fluxes of heat and moisture, and possibly radial convergence of moisture from ATOLL charts (Analysis of the Tropical Oceanic Lower Layer) with adjusted wind velocity for the sea surface, be computed to further confirm and utilize the predictive information available through sea surface temperature data.

Acknowledgments

I wish to thank Mrs. Margaret Robinson for supplying the monthly means and Mr. Fred Zbar for the data check program. Mr. James Trout and Mr. Eddy Ramariz aided in solving several difficult programming problems. The wise council of the staff of NHC, particularly Dr. Banner Miller, is greatly appreciated. Messrs. Dale Martin, David Shields, and David Senn assisted with the graphics.

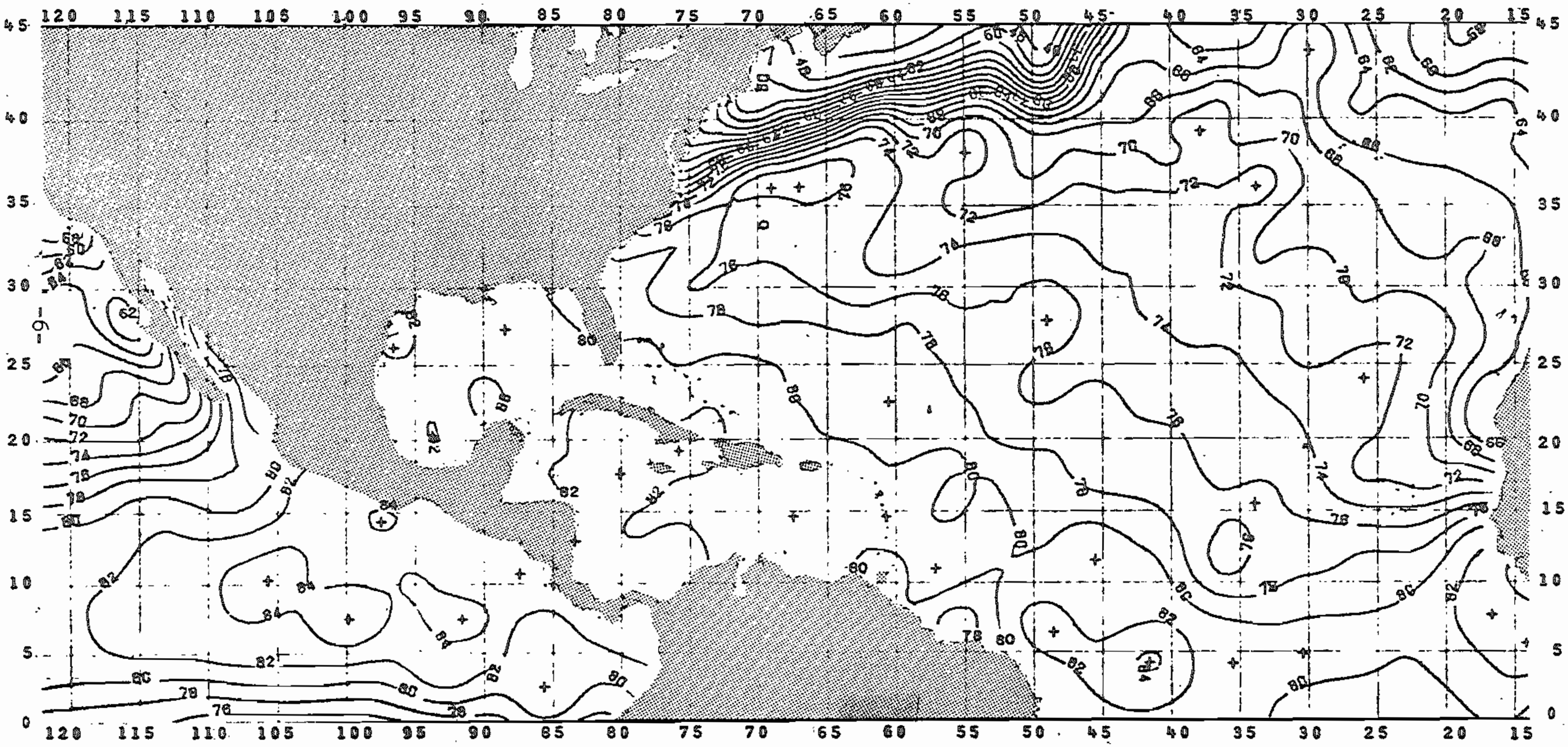


FIGURE 1. SEA SURFACE TEMPERATURES (FAHRENHEIT) 13 JUNE - 17 JUNE 1972

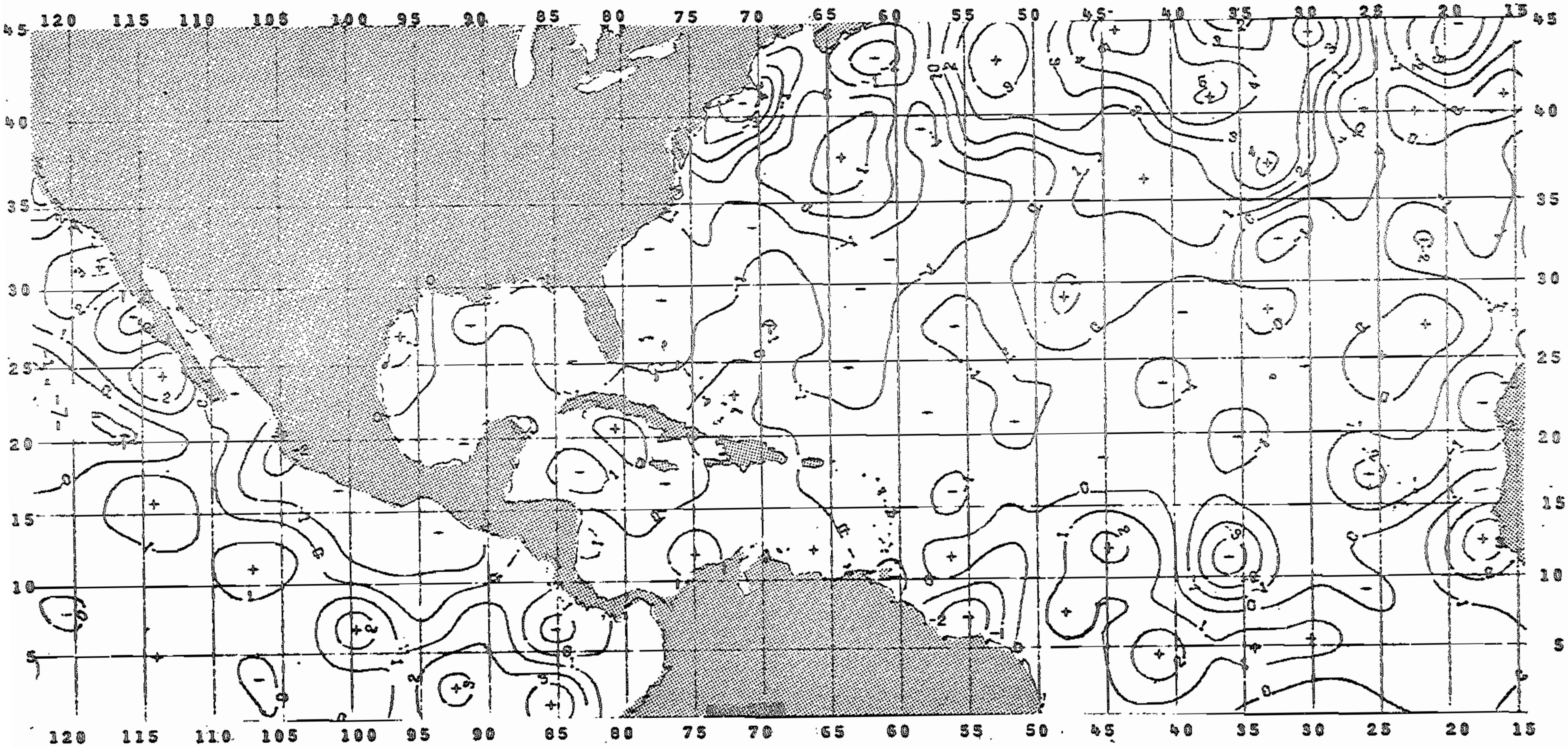


FIGURE 2. SEA SURFACE TEMPERATURE ANOMALIES (FAHRENHEIT) 13 JUNE - 17 JUNE 1972

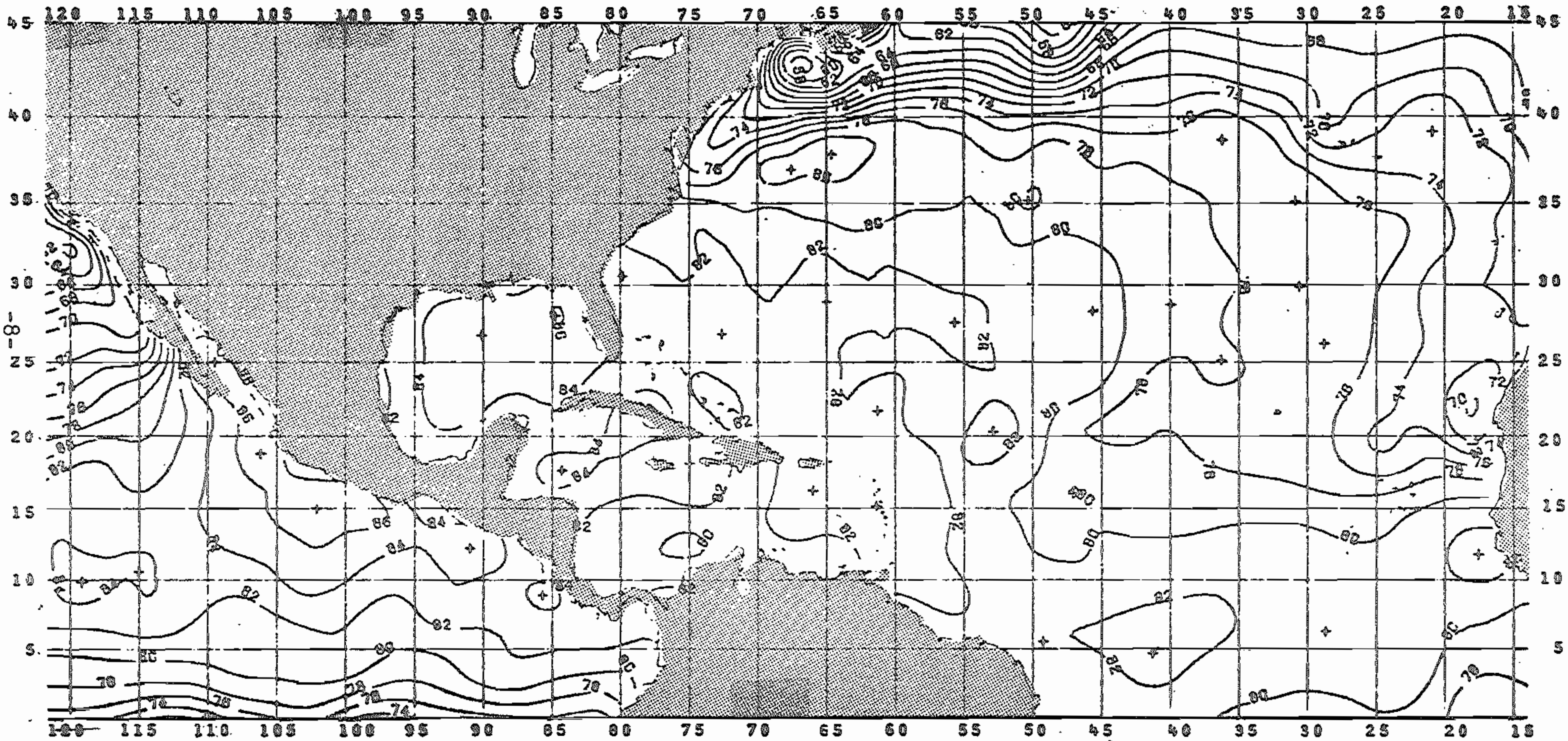


FIGURE 3. SEA SURFACE TEMPERATURES(FAHRENHEIT) 13 AUG. - 17 AUG. 1972

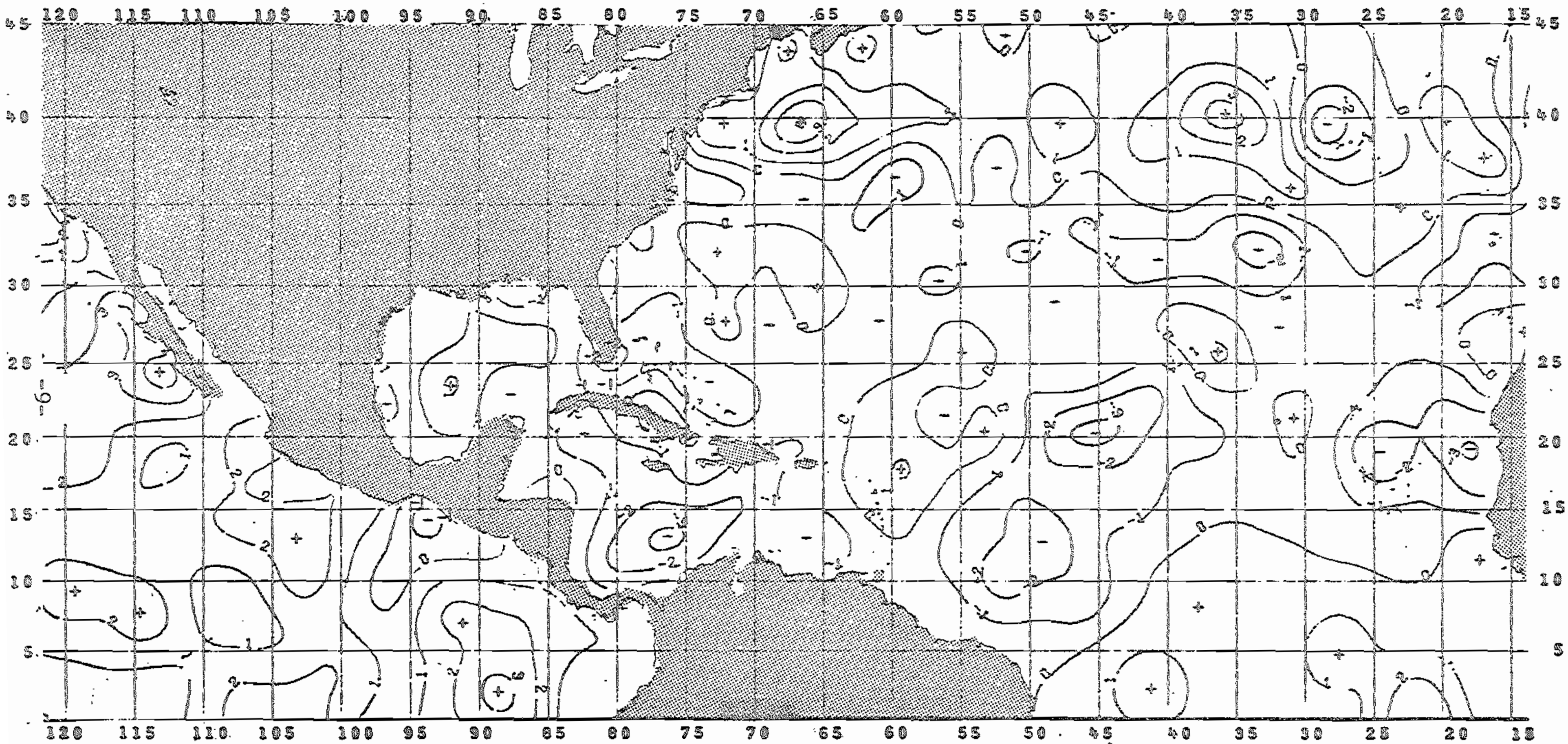


FIGURE 4. SEA SURFACE TEMPERATURE ANOMALIES (FAHRENHEIT) 13 AUG. - 17 AUG. 1972

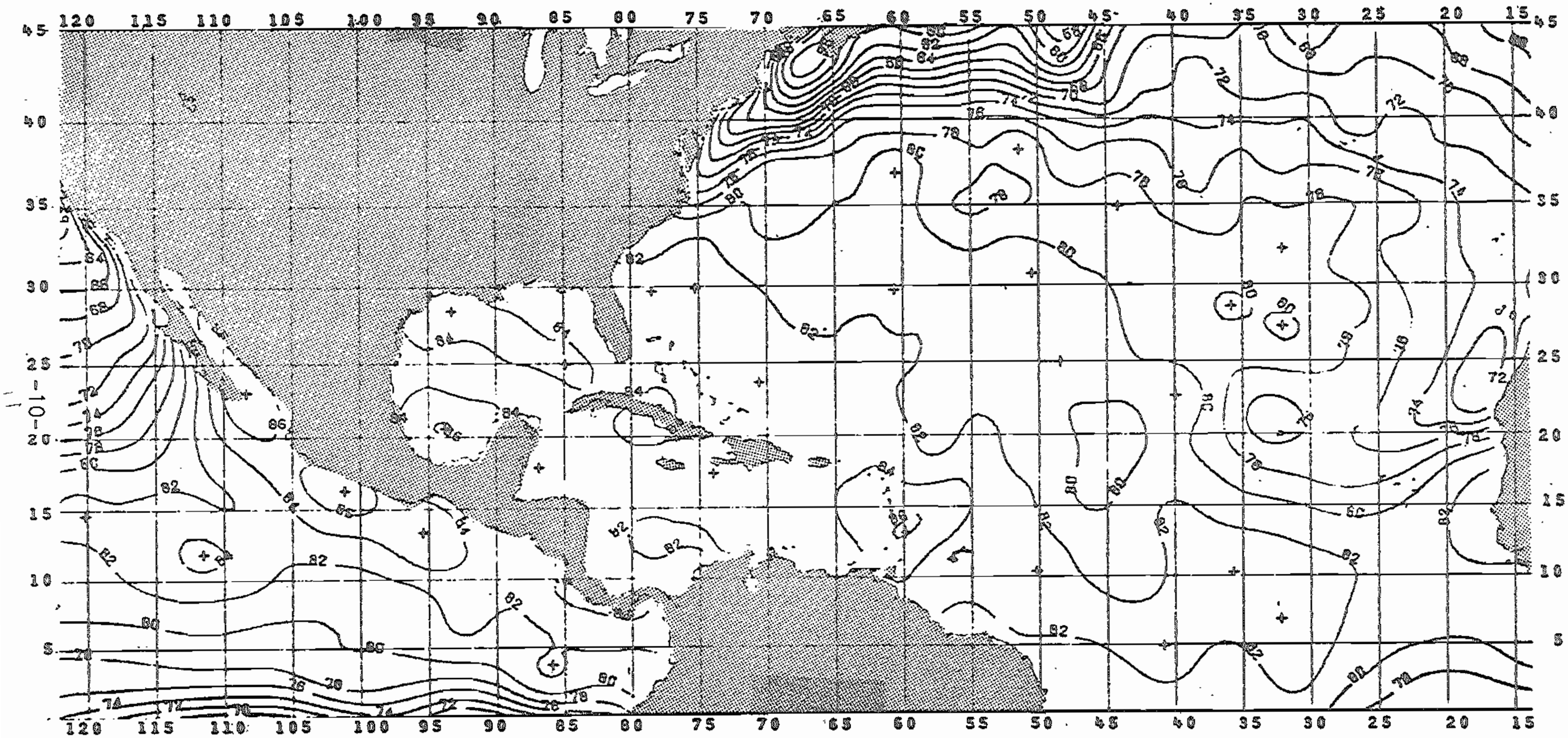


FIGURE 5. SEA SURFACE TEMPERATURES (FAHRENHEIT) 13 SEP. - 17 SEP. 1972

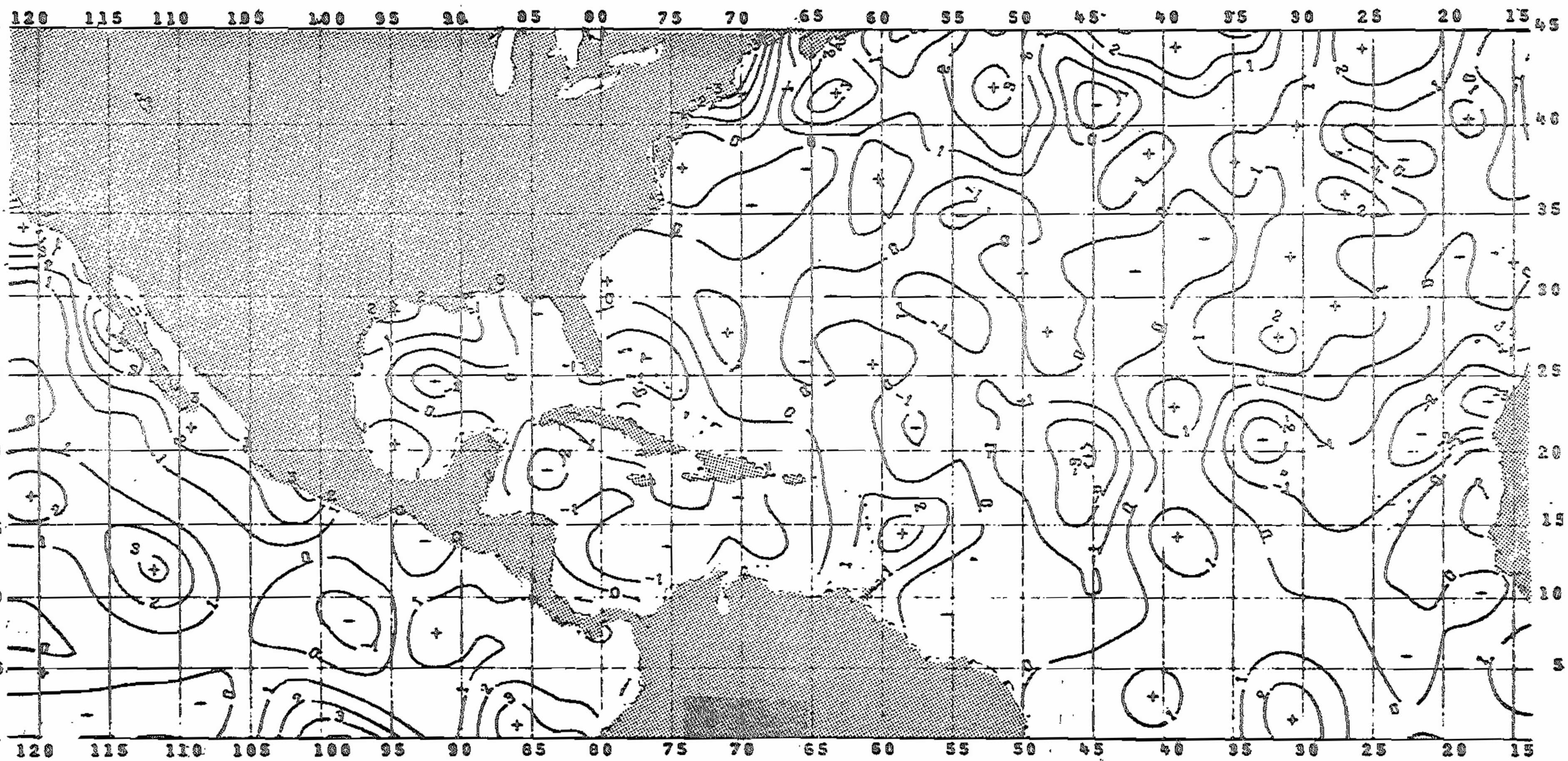


FIGURE 6. SEA SURFACE TEMPERATURE ANOMALIES (FAHRENHEIT) 13 SEP. - 17 SEP. 1972

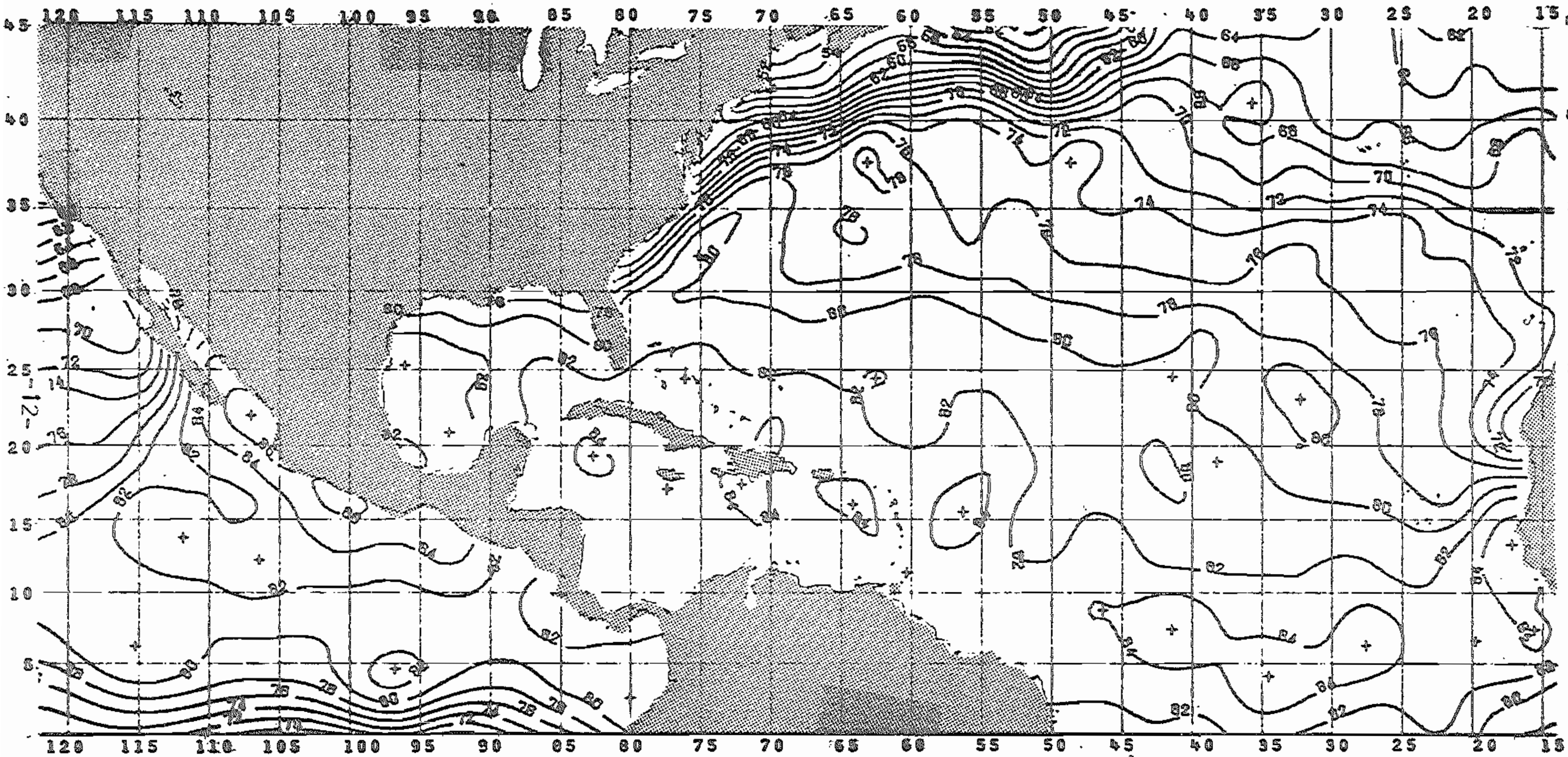


FIGURE 7. SEA SURFACE TEMPERATURES (FAHRENHEIT) 13 OCT. - 17 OCT. 1972

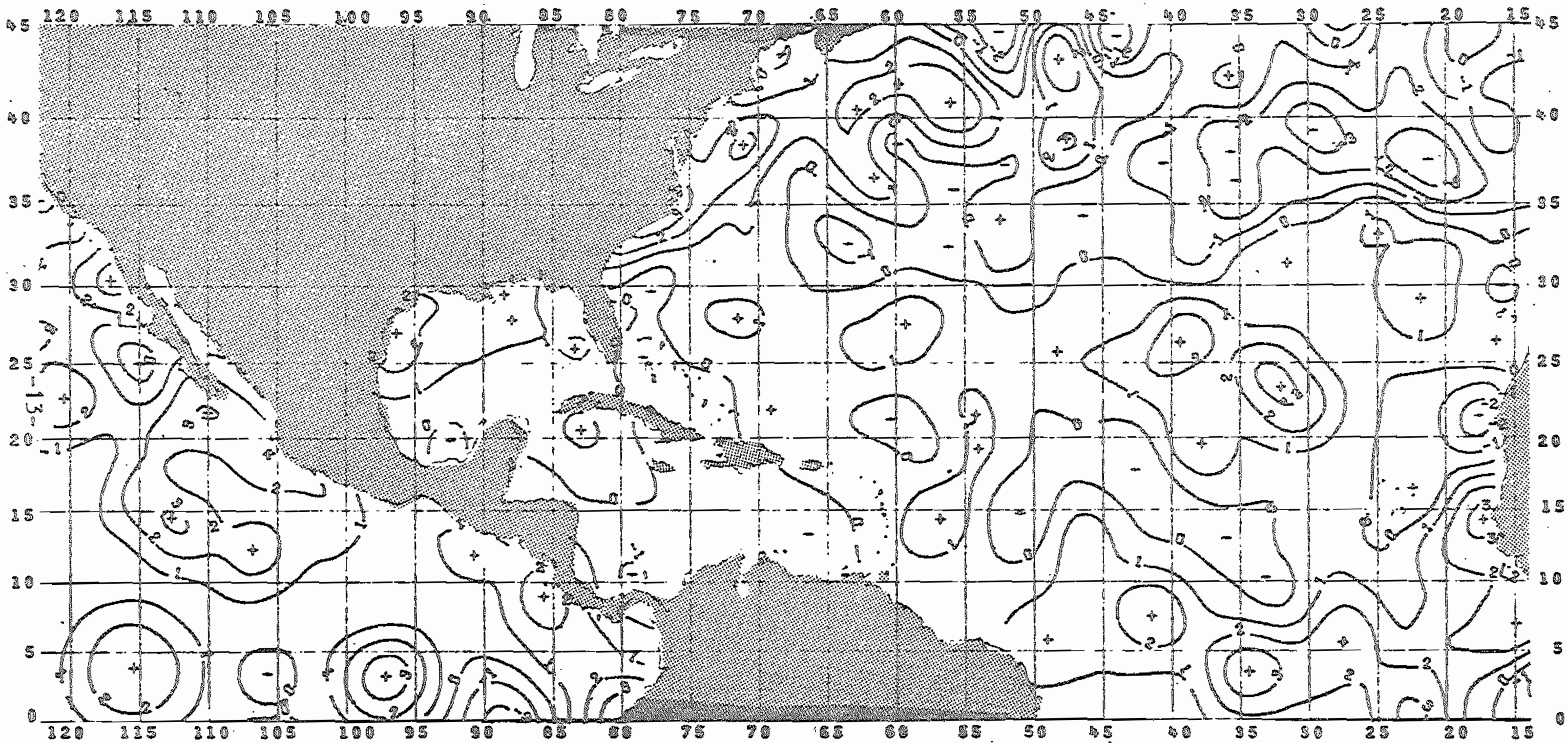


FIGURE 8. SEA SURFACE TEMPERATURESANOMALIES (FAHRENHEIT) 13 OCT.- 17 OCT.1972

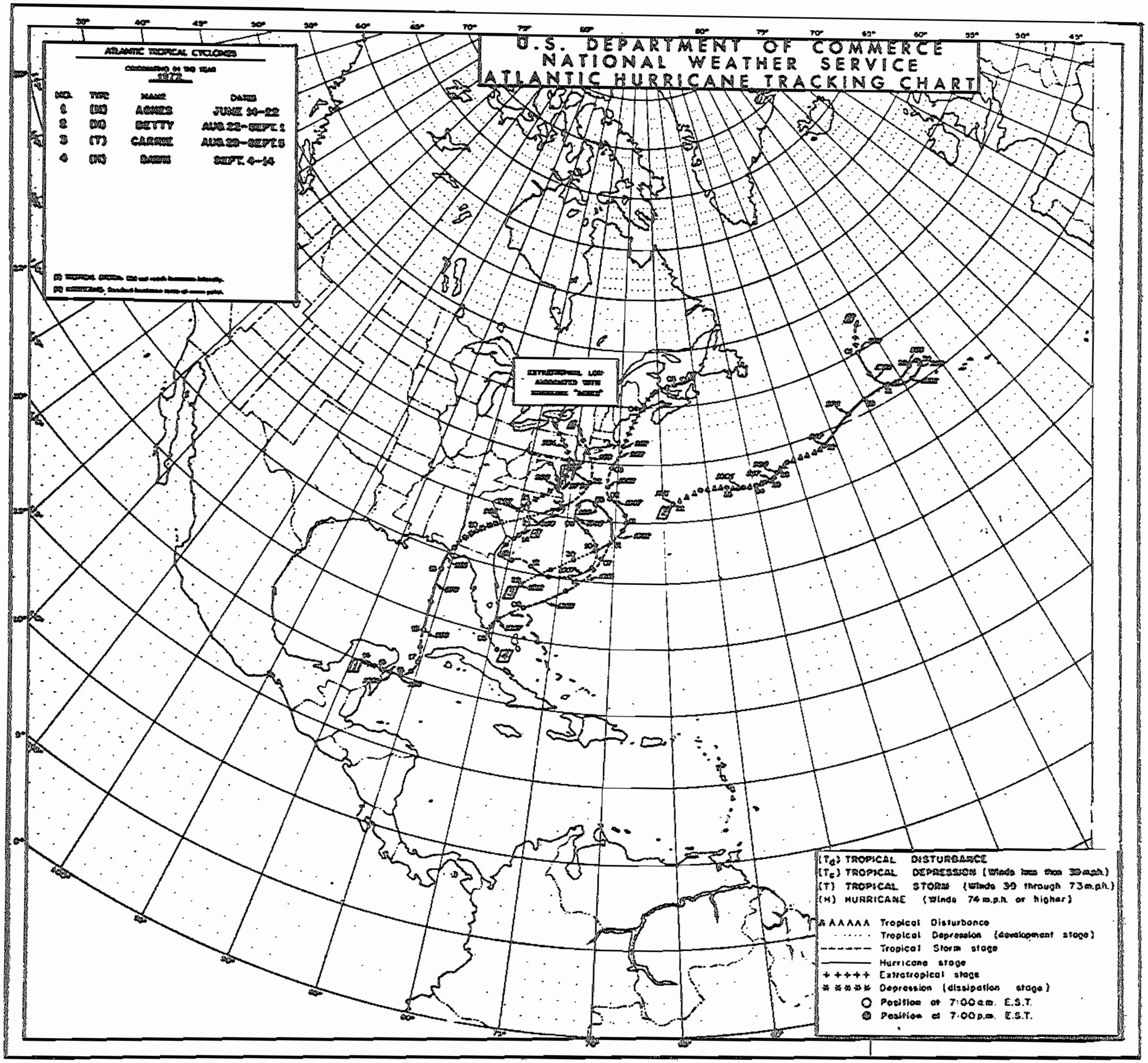
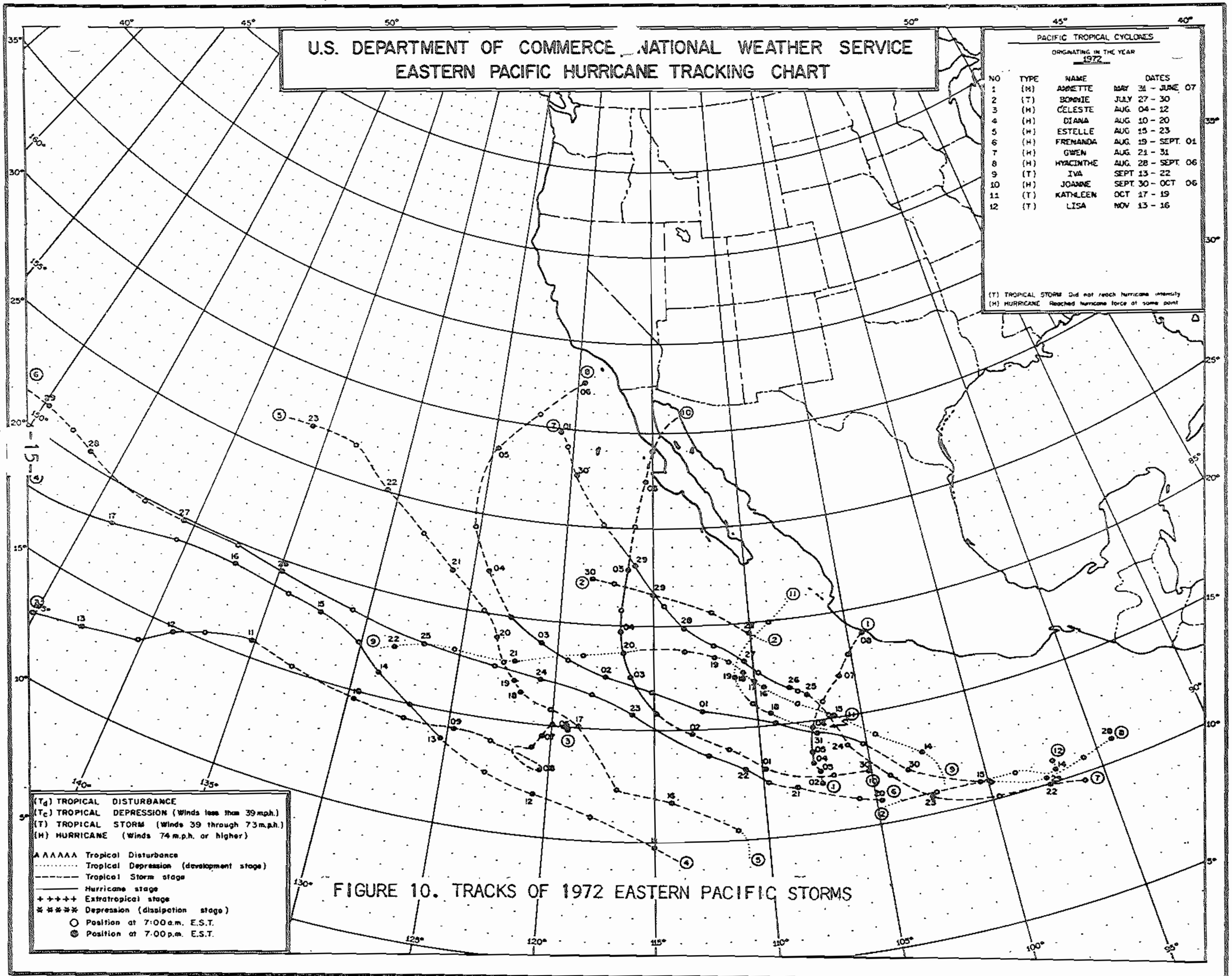


FIGURE 9. TRACKS OF THE 1972 ATLANTIC STORMS



NO	TYPE	NAME	DATES
1	(H)	ANNETTE	MAY 31 - JUNE 07
2	(T)	BONNIE	JULY 27 - 30
3	(H)	CELESTE	AUG. 04 - 12
4	(H)	DIANA	AUG. 10 - 20
5	(H)	ESTELLE	AUG. 15 - 23
6	(H)	FRENANDA	AUG. 19 - SEPT. 01
7	(H)	GWEN	AUG. 21 - 31
8	(H)	HYACINTHE	AUG. 28 - SEPT. 06
9	(T)	IVA	SEPT. 13 - 22
10	(H)	JOANNE	SEPT. 30 - OCT. 06
11	(T)	KATHLEEN	OCT. 17 - 19
12	(T)	LISA	NOV. 13 - 16

FIGURE 10. TRACKS OF 1972 EASTERN PACIFIC STORMS

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